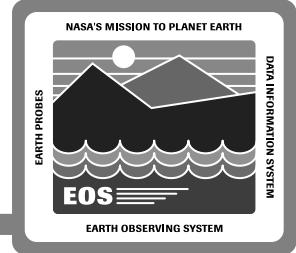


FOS Real Time Software Architecture

Ken Fregeolle

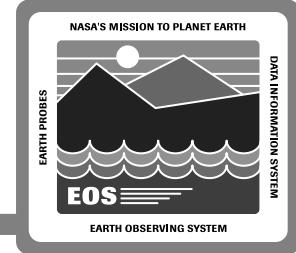
17 October 1995

Real-time Architecture Overview



- Architecture Objectives
- Subsystem Overviews
 - Concepts and Features
 - Subsystem Processes
 - Process - Hardware Map
- Hardware Utilization
- Task Distribution
- Introductions

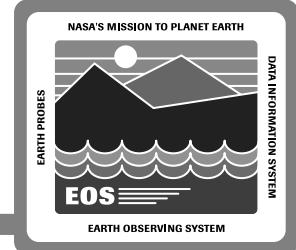
Real-time Architecture Objectives



Key Design Drivers

- Maximize utilization of spacecraft contact periods
 - Avoid single points of failure
 - Provide quick failure detection and recovery mechanism
 - Maximize configuration flexibility
 - Automate / minimize routine FOT contact activities
- Easily scale to accommodate multi-mission support
 - Isolate affects of changes due to mission unique requirements
 - Create performance-oriented, modular and reusable components (tools and blackbox engines)
 - Make intelligent performance vs. flexibility trades
 - Strive for bi-directional scalability (both upward and downward)
 - Ensure single point of command for each spacecraft

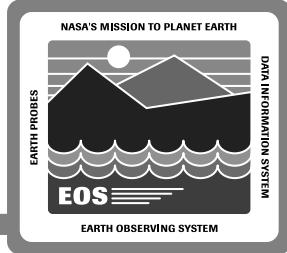
Real-time Subsystems Overview



Comprised of four (4) software subsystems

- Resource Management (RMS)
- Telemetry (TLM)
- Command (CMD)
- Real-time Contact Management (RCM)

Resource Management Subsystem

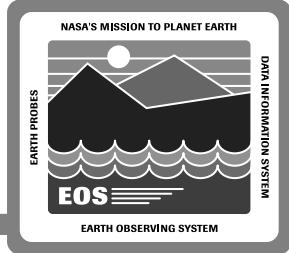


Concepts and Features

Logical String

- Manages a collection of resources supporting a specific FOS functionality (e.g. real-time contact, simulation, historical data replay)
- Logically distributes / separates real-time, simulation, and test activity functions across server and workstation hardware resources
 - Multiple strings may be active on any given FOS node
 - Scales well with addition of multi-missions support requirements and hardware
- Provides FOT and IST users shared view and participation in FOS activities
 - Single user may join multiple logical strings
 - Multiple users may join same logical string

Resource Management Subsystem

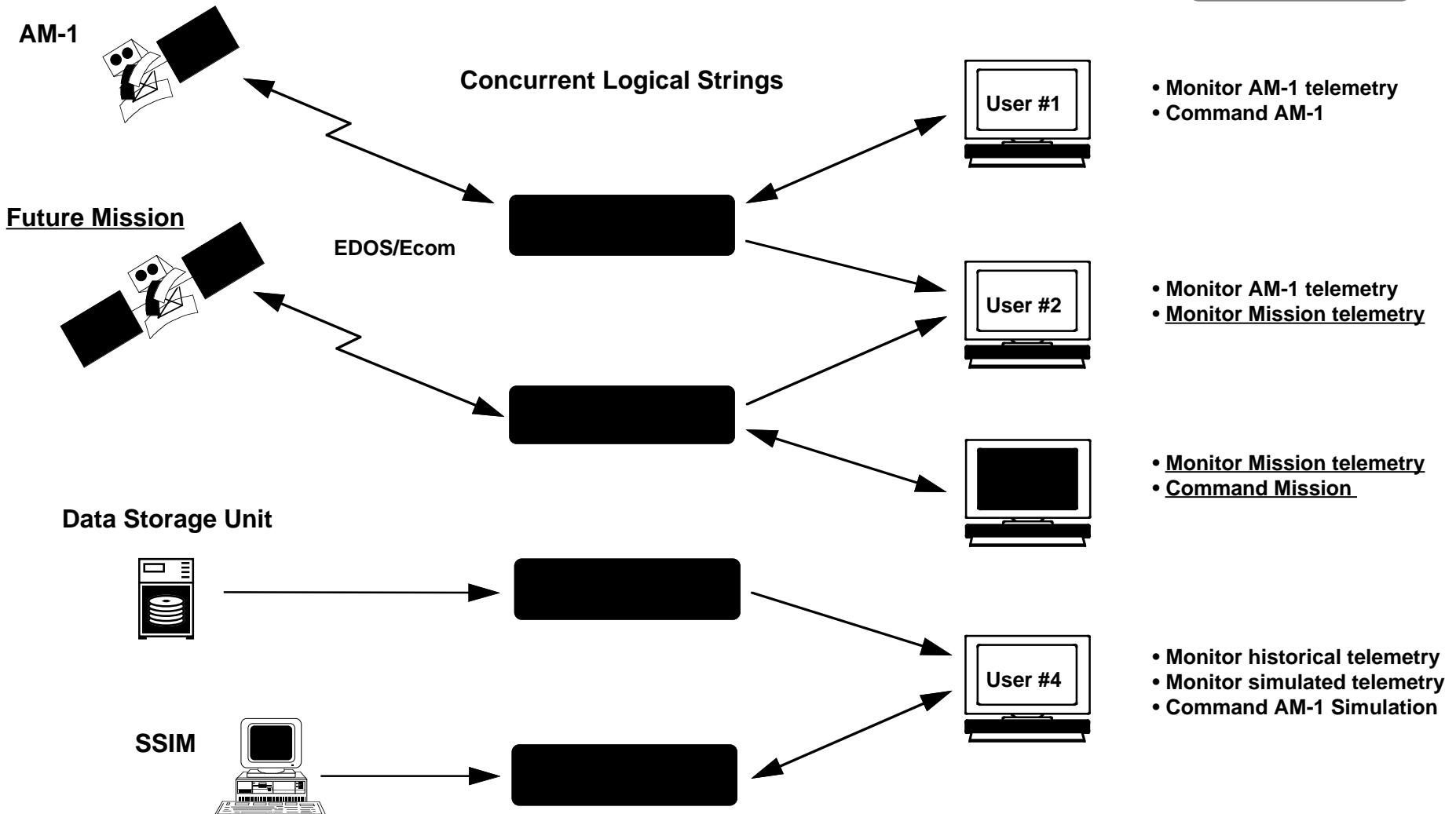
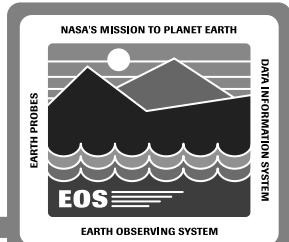


Concepts and Features

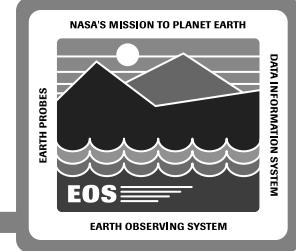
Logical String (cont.)

- Facilitates EOC real-time contact automation
 - Default and script-driven configurations
 - FOT or IST user connection not required
Critical real-time processing occurs on RTS
- Performs fail-over of critical real-time processes
- Guarantees spacecraft single point of command within the EOC

Resource Management Subsystem



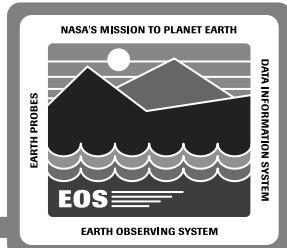
Resource Management Subsystem



Subsystem Processes

- **String Manager (prototyped)**
 - Configures, manages, and provides view of logical strings
 - Ensures single point of spacecraft commanding in the EOC
 - Manages string fail-over
- **Resource Monitor**
 - Provides monitoring service for critical EOC resources
 - Reports EOC anomalous hardware and software status

Resource Management Subsystem



Real-Time Server

String Manager
Resource Monitor

NCC Input
NCC Output
EDOS Input
EDOS Output

Format Command
FOP Command
Transmit Command

Decom
Memory Dump
State Check
Parameter Server

COTS

Data Server

User Station

IST

String Manager

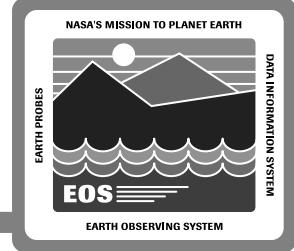
Decom
Parameter Server

COTS

String Manager

Decom
Parameter Server

COTS

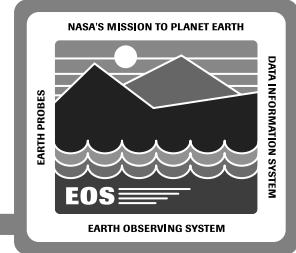


Telemetry Subsystem

Concepts and Features

- One architecture for all FOS spacecraft and instrument telemetry processing
 - Telemetry engines run on any FOS server or workstation node
 - Replication - client application distribution across hardware
 - Single decommutation engine serves multiple applications simultaneously
 - Centralization - loose client application coupling
- Real-time configurable selective decommutation increases scalability and hardware exploitation
 - Additional / concurrent Real-time and Off-line activities (e.g. real-time multi-mission instrument monitoring or off-line analysis farm)

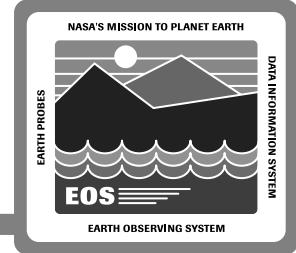
Telemetry Subsystem



Concepts and Features

- **Selective Decommunication**
 - Allows real-time, user alteration of telemetry parameter decommutation and processing
 - Reduces host processing load
 - Processing not performed on unwanted information
(e.g. monitoring three parameters requires decommutation of only those three parameters)
 - Does not require data-base redefinition
- **Comprehensive Decommunication**
 - Ensures decommutation / processing of all available telemetry parameters

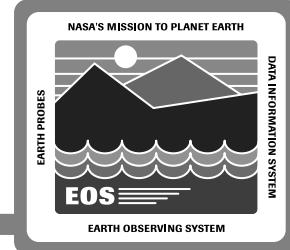
Telemetry Subsystem



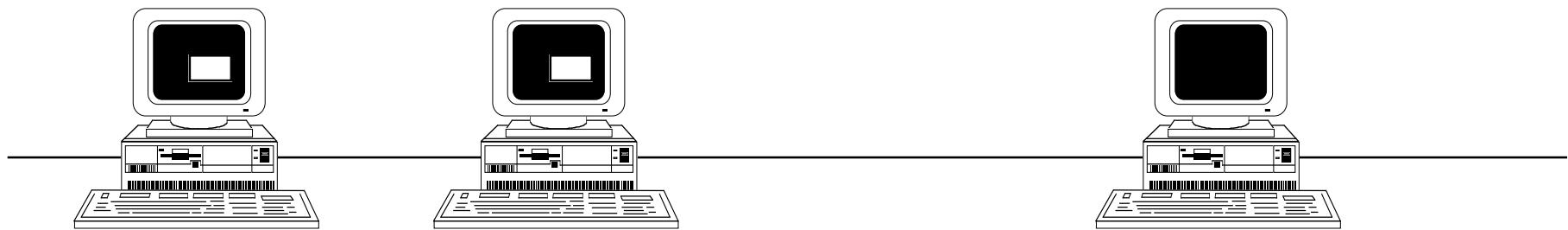
Concepts and Features

- Mirrored Decommunication Configuration
 - Locally cloned comprehensive telemetry processing configuration
 - Maintains configuration synchronized to master RTS comprehensive decommutation process
 - Common telemetry view with single point of configuration control
 - Managed by RMS
- Tailored Decommunication Configuration
 - Permits custom configuration not affecting, or affected by, comprehensive or mirrored processing
 - Alteration of default values (e.g. limits)
 - Selective decommutation of telemetry parameters

Telemetry Subsystem



Mirrored Configuration

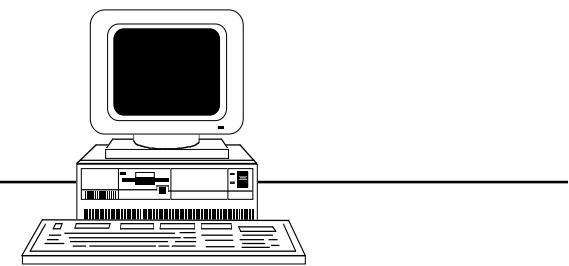


Flight Engineers

AM-1 Housekeeping Telemetry

- Global Configuration Control
 - * default limits
- Comprehensive Decom

Tailored Configuration

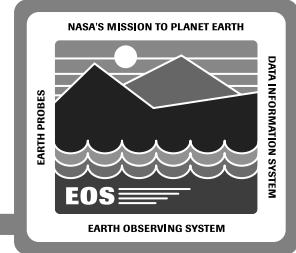


Instrument Analyst

AM-1 Housekeeping Telemetry

- Local Configuration Control
 - * users adjusted limits
- Selective Decom
 - * CERES parameters

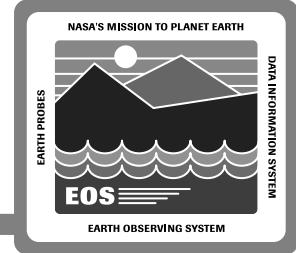
Telemetry Subsystem



Concepts and Features

- **Telemetry-driven Derived Parameter calculation**
 - Ensures coherent evaluation mechanism and results for Real-time and Off-line functions
 - Uses spacecraft clock packet time to determine evaluation period
Consistent results when processing telemetry at real-time or alternate stream rate (e.g. 12 x)

Telemetry Subsystem

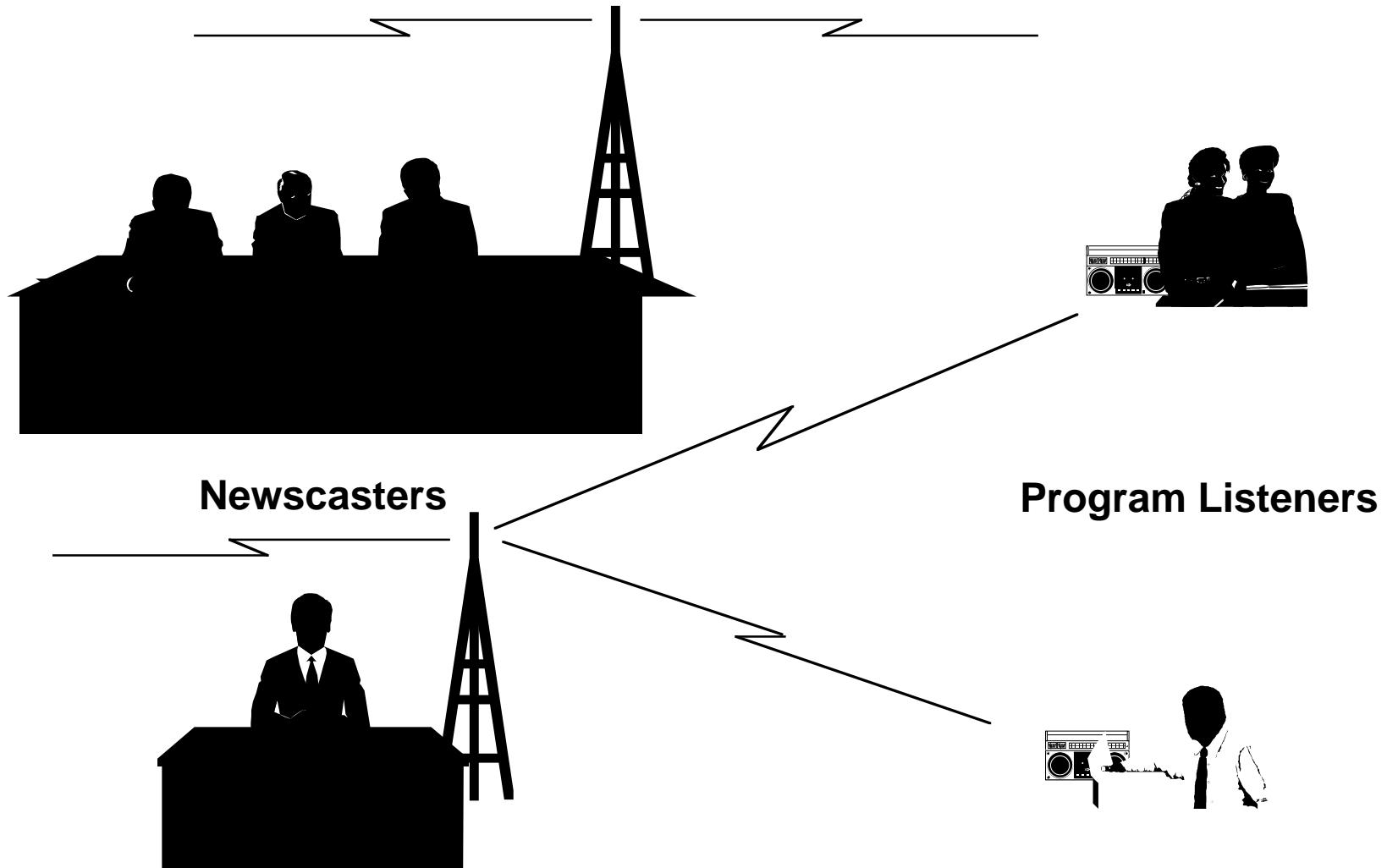
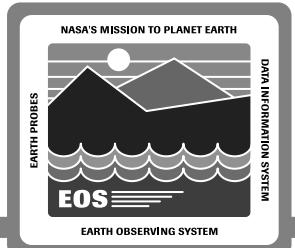


Concepts and Features

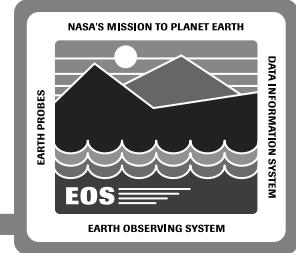
Producer-Consumer Paradigm

- An information delivery model which promotes loose coupling and location independence between product users and product providers.
 - Producers not aware of types or number of Consumers
 - Consumers able to “select” desired products
 - Producers and Consumers need not be co-located
- Radio Broadcasting Example :
 - Information Provider **Newscaster**
 - Information Delivery Mechanism
 - Transmission (broadcast) **Radio transmission station**
 - Reception (tuned) **Radio receiver**
 - Information Consumer **Program listener**

Telemetry Subsystem



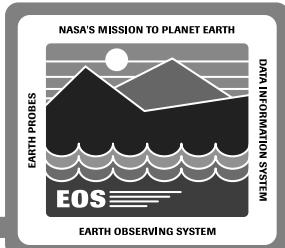
Telemetry Subsystem



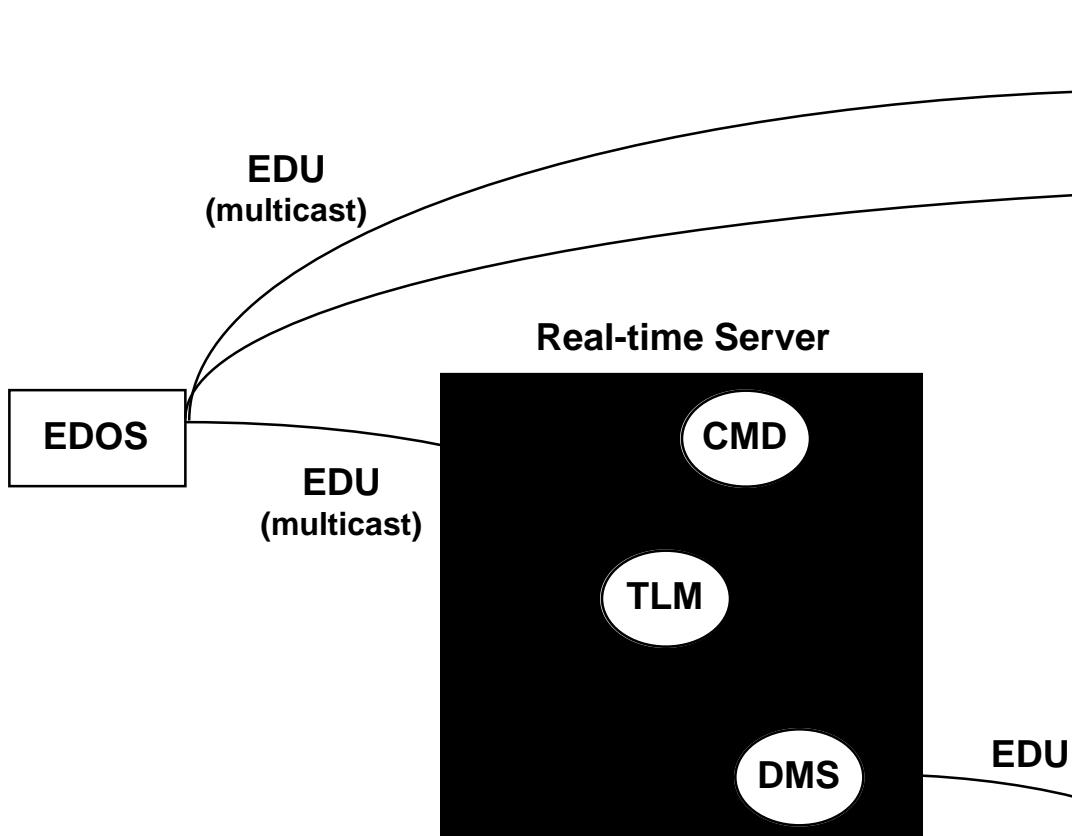
Application of Paradigm (Telemetry Multicast)

- **Telemetry Providers** multicast raw telemetry information
 - Network message addressing technique
 - One message sent simultaneously to multiple nodes
 - Lower bandwidth utilization due to distribution of raw data versus processed data
- **Telemetry Consumers** “tune-in” to selected telemetry stream
 - Decommutation engines listen to “Group Address”
- **Telemetry Producers and Consumers** are loosely coupled
 - Telemetry providers not affected by decommutation engines
 - Sending node sends only one message
 - New recipients added to Group without increasing load

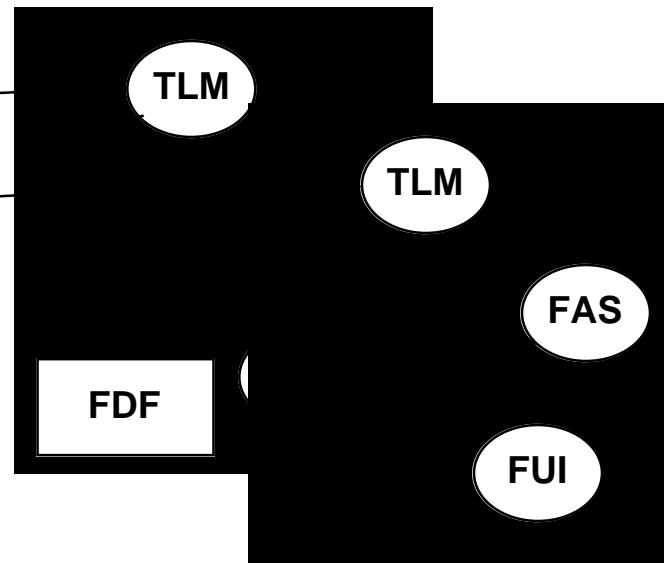
Telemetry Subsystem



Multicast Telemetry Delivery



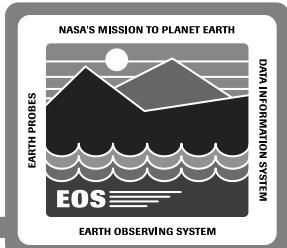
User Station



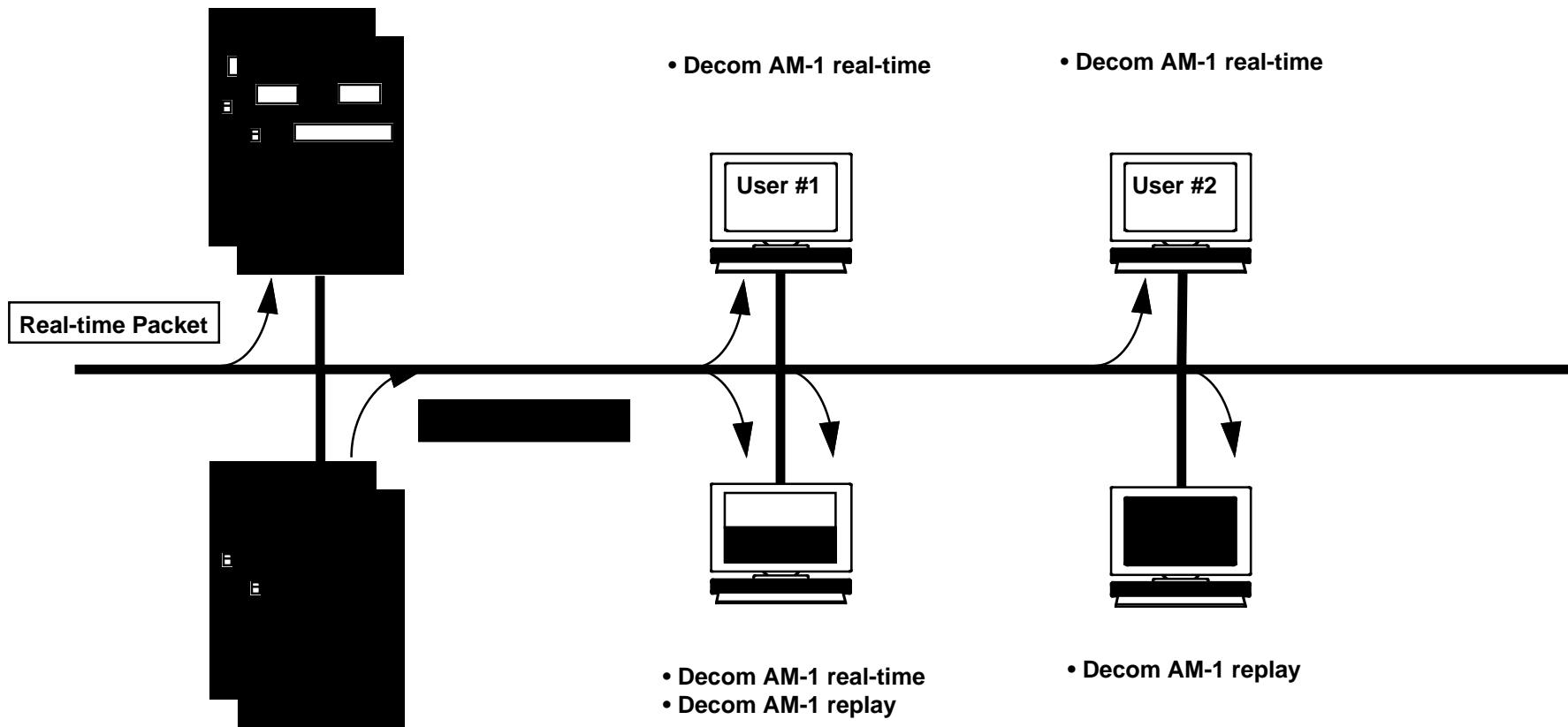
Data Storage Unit



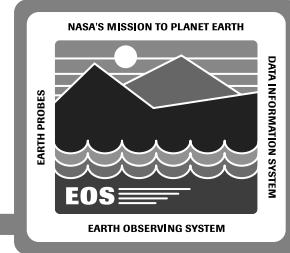
Telemetry Subsystem



Multicast Telemetry Delivery



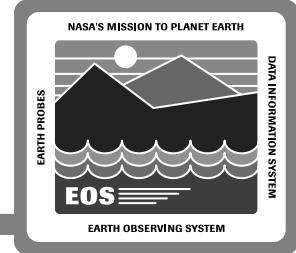
Telemetry Subsystem



Application of Paradigm (Parameter Server)

- Parameter Consumers request “selected” telemetry parameter subset
 - Parameter Server delivers to each application only parameter updates of interest
- Parameter Producers manufacture parameters and drive update rate
 - Parameter Server forwards parameters synchronously
- Parameter Producers and Consumers are loosely coupled
 - Decommunication engines, Parameter Servers, and Client applications are location independent
 - Decommunication engines know nothing about client applications
 - Decommunication engine performance not affected by clients

Telemetry Subsystem



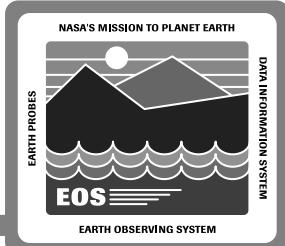
Parameter Server PDR design

- Parameter Server tied to Decom engine
 - Duplicated for each process that serves parameters
 - Separate connection required for each telemetry type

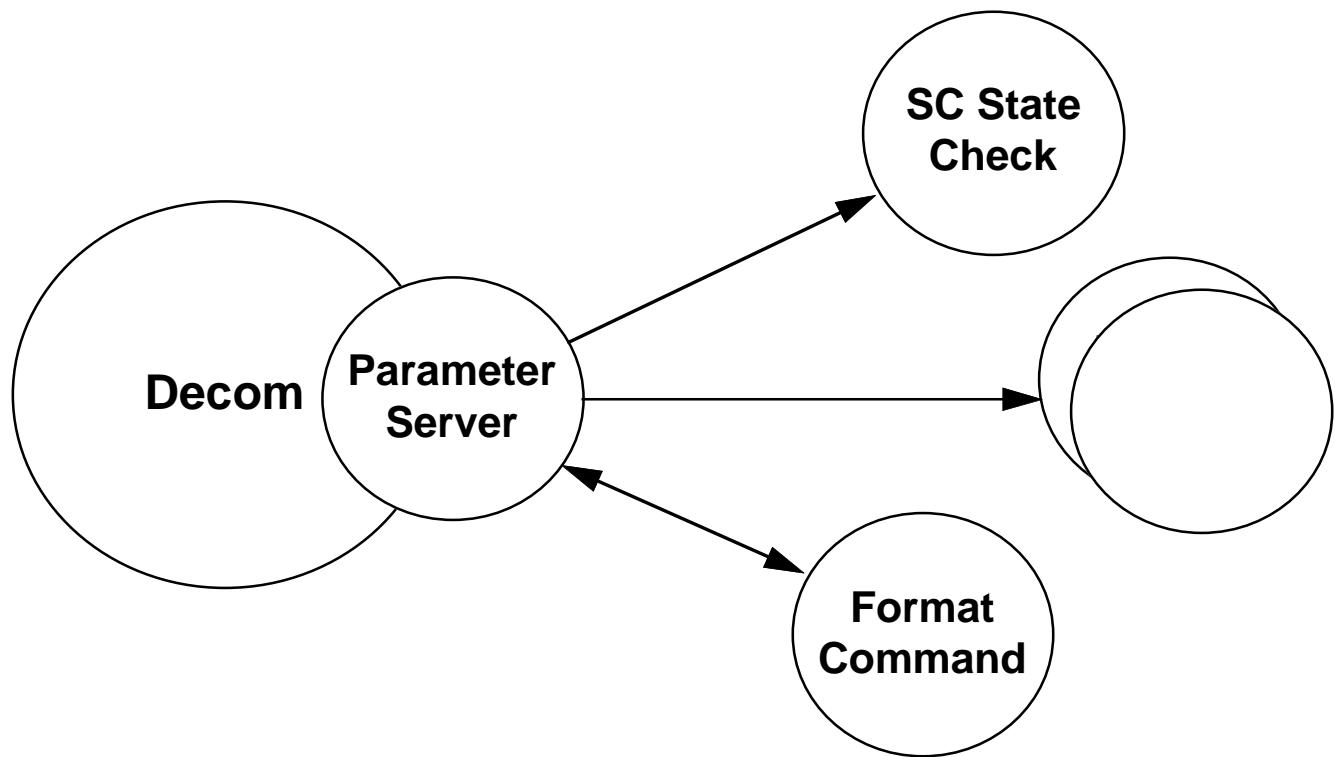
Design migration factors

- Common Parameter Work Group
 - What information needs to be served?
 - How many processes serve out information?
- Parameter Server Work Group
 - How can we serve out information efficiently?
 - How can we satisfy clients needs for information served in different ways?

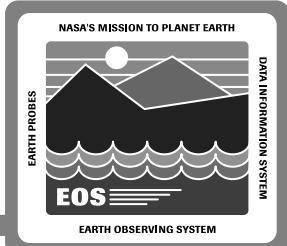
Telemetry Subsystem



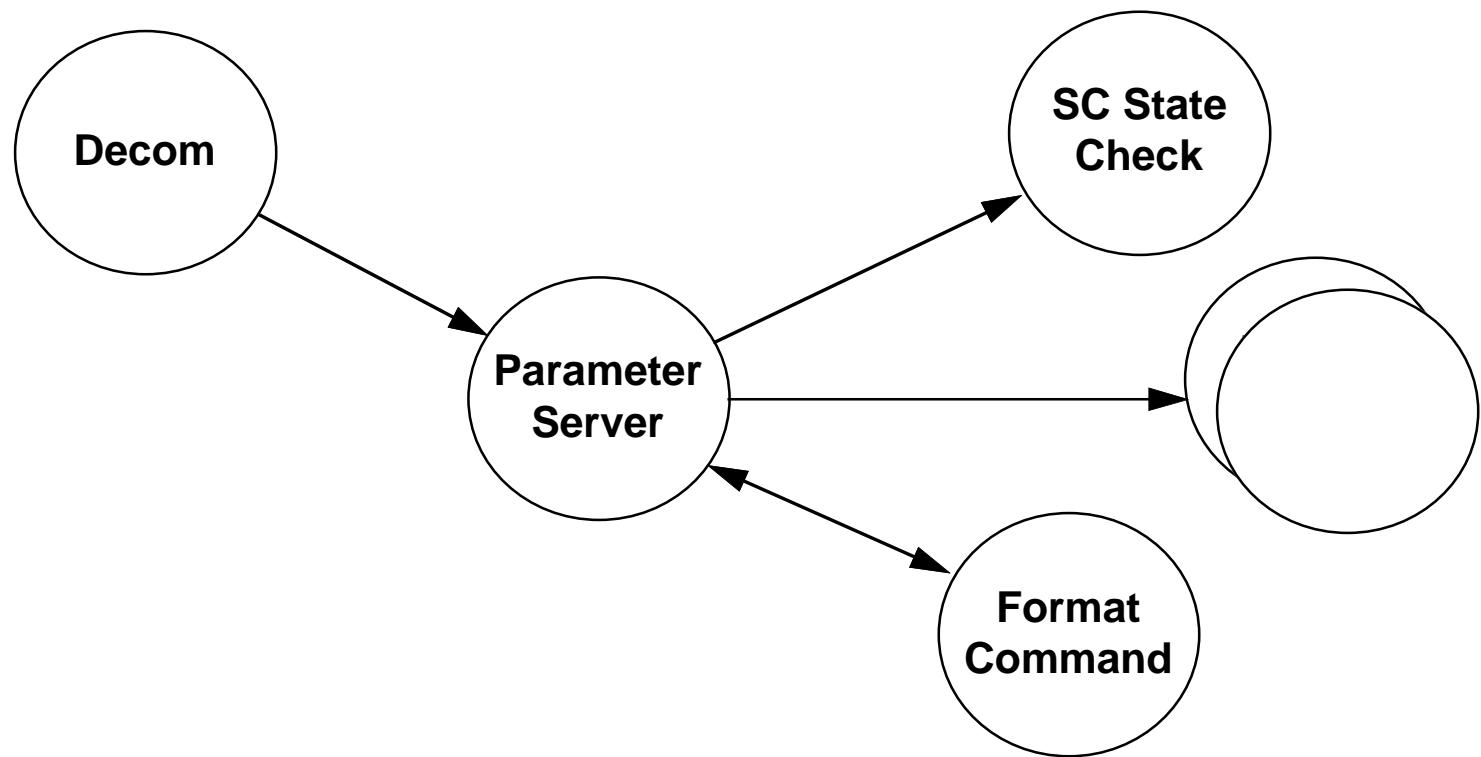
PDR Telemetry Subsystem Design

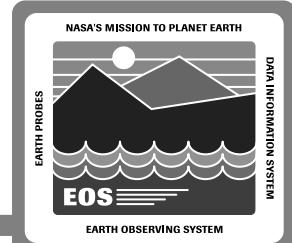


Telemetry Subsystem



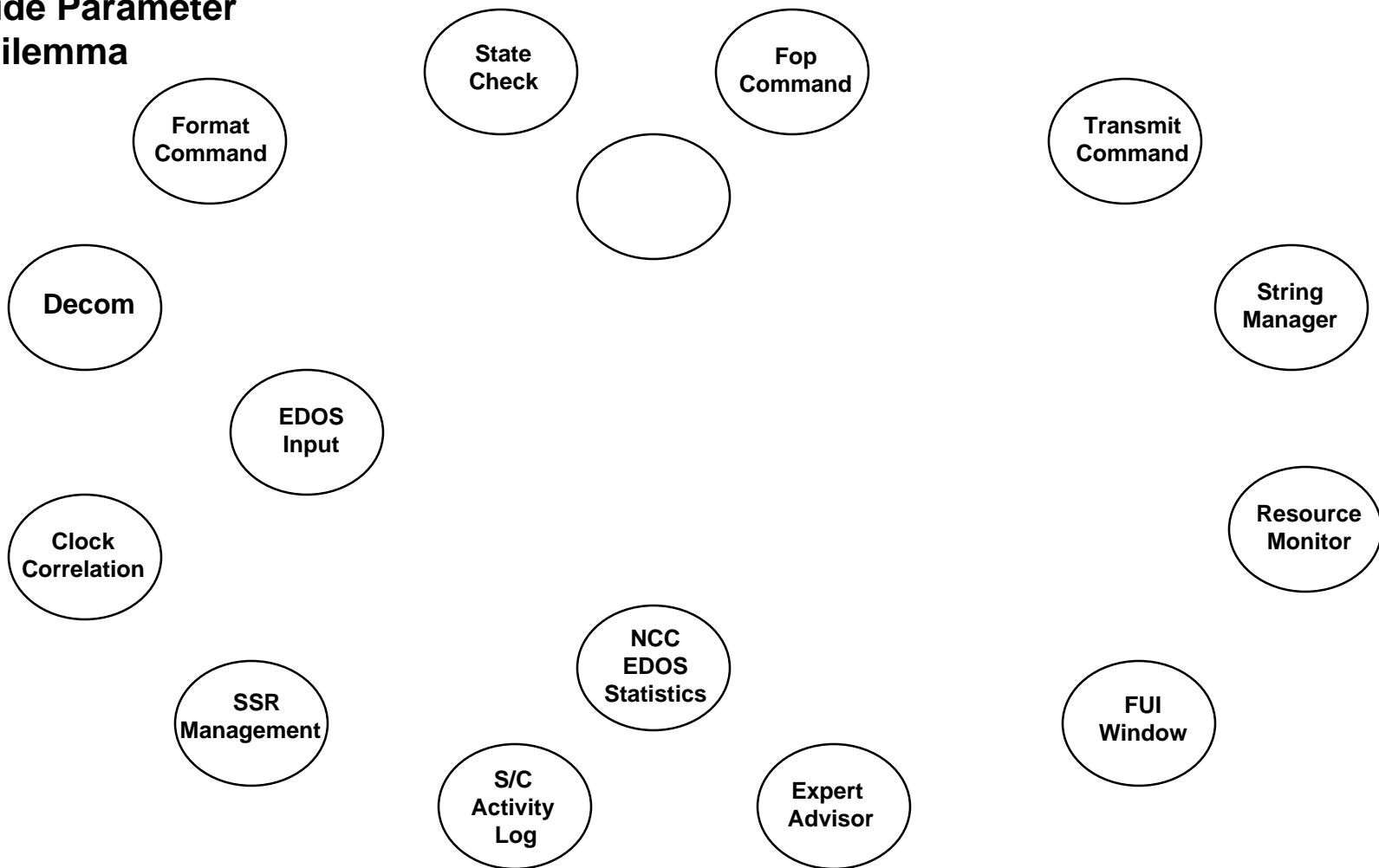
Post-PDR Telemetry Subsystem Design



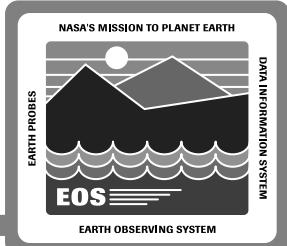


Telemetry Subsystem

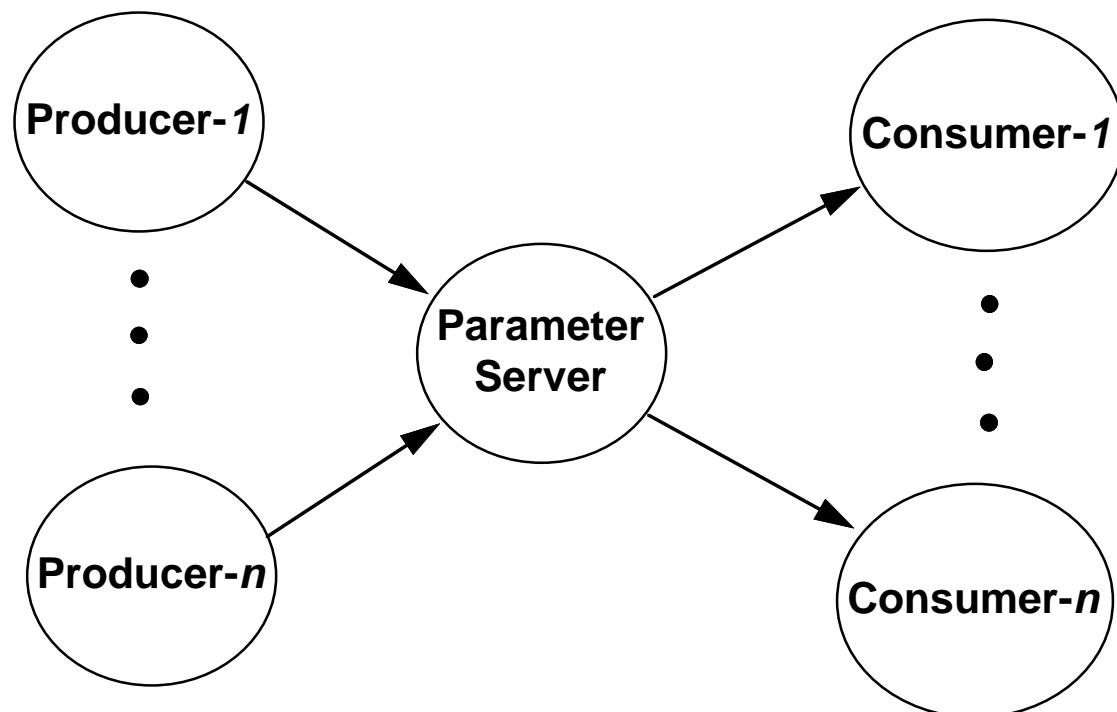
System-wide Parameter Delivery Dilemma



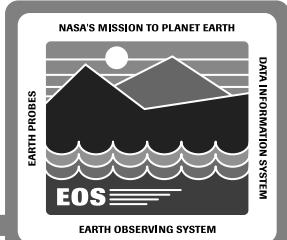
Telemetry Subsystem



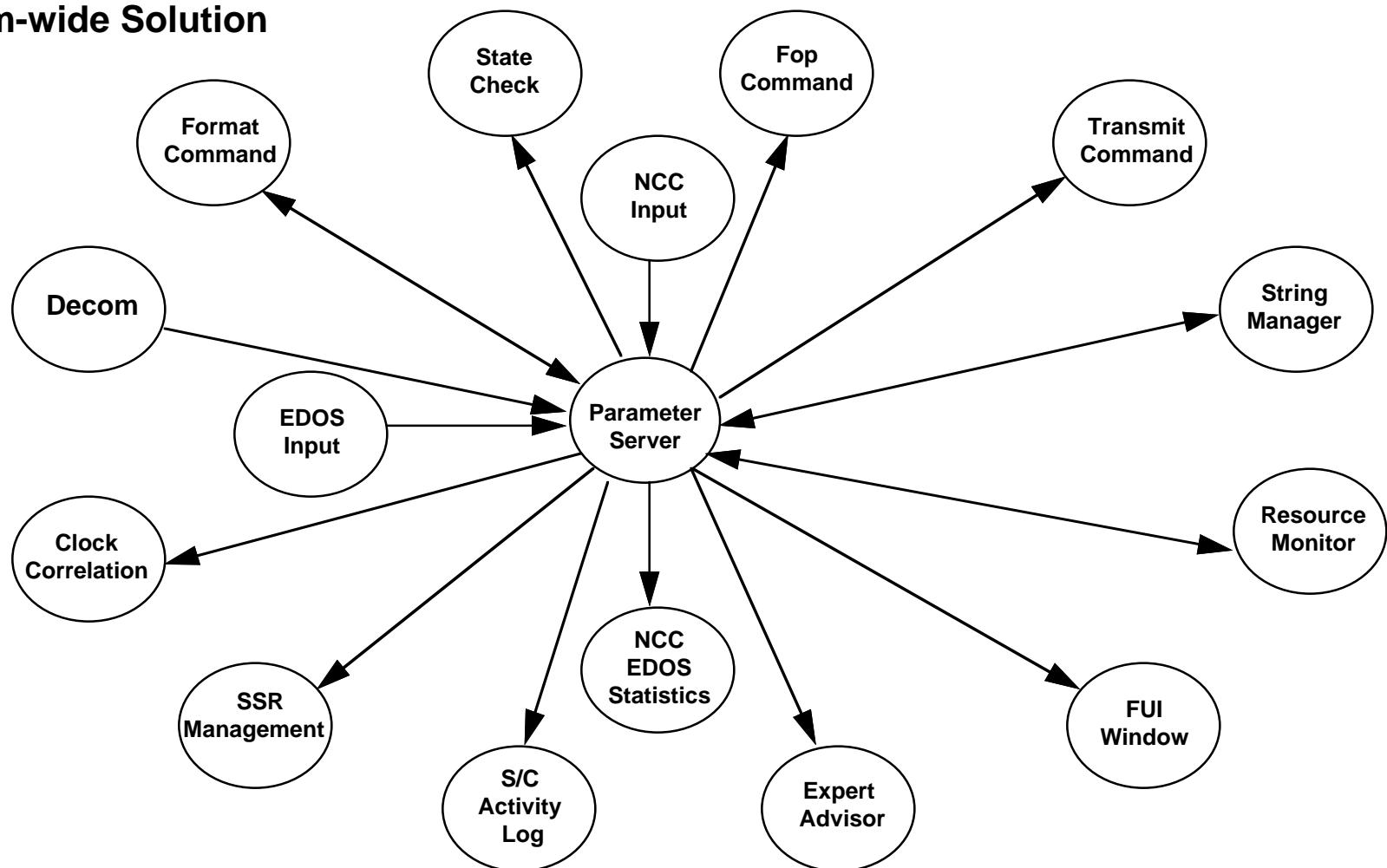
CDR System-wide Design



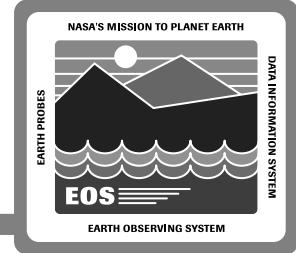
Telemetry Subsystem



System-wide Solution



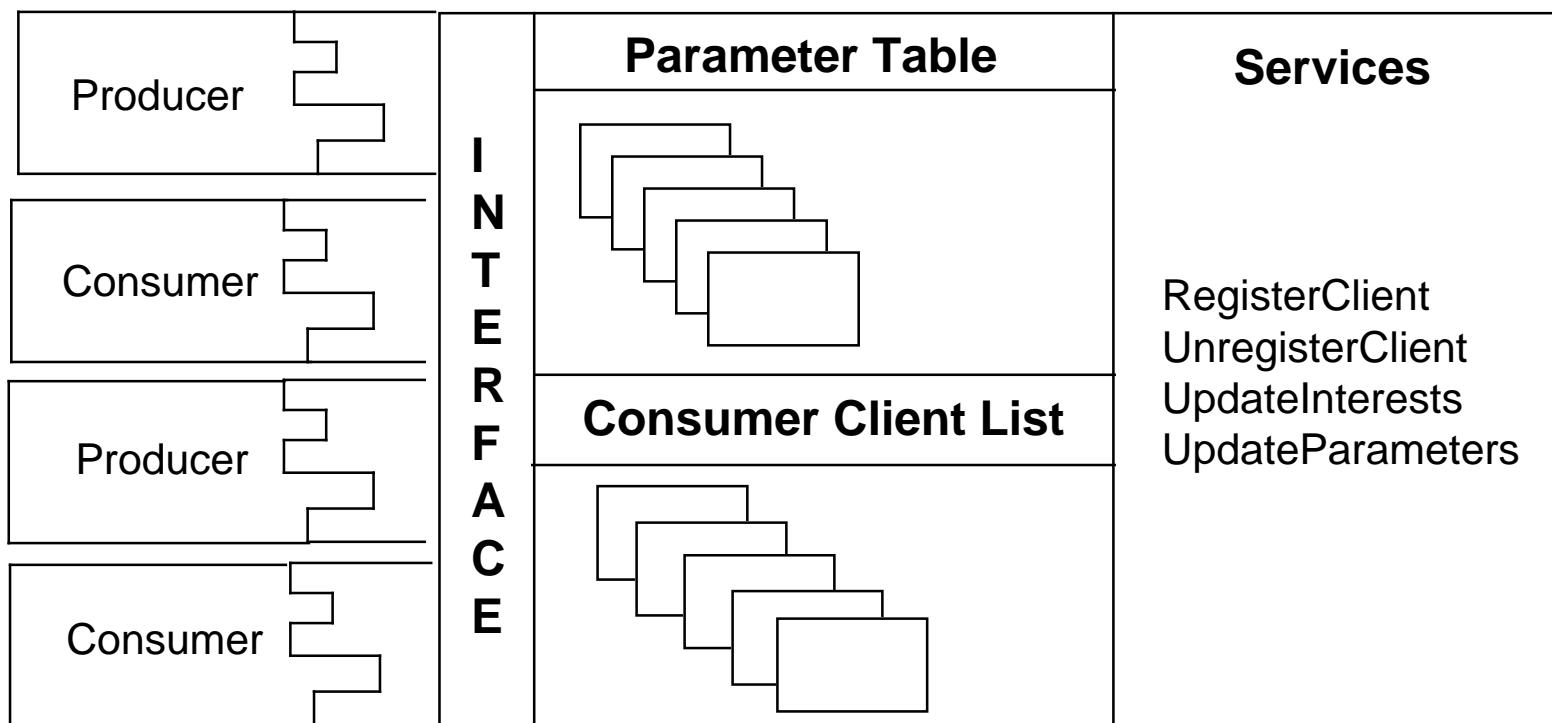
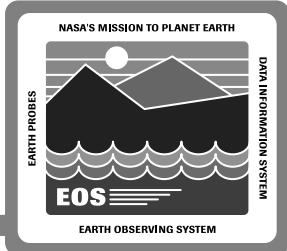
Telemetry Subsystem



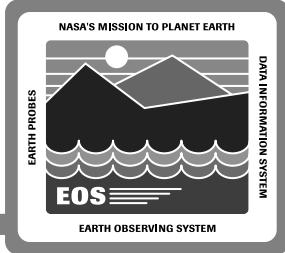
Parameter Server Design

- Shared repository for telemetry information
 - Holds current values of all producer supplied parameters
(e.g. raw, decoded, EU-converted, status flag values)
Parameter Table implemented using dictionary model
- Common client interface
 - Services available to all clients
Clients can be producers and / or consumers
- Tracks current consumer clients and client interests
 - Client information held within local Client List
 - Producer tracking not required

Telemetry Subsystem



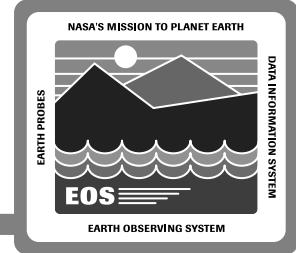
Telemetry Subsystem



Flexible Client registration

- Server provides distinct modes of parameter delivery
 - One shot delivery of current values of parameters
(e.g. Command prerequisite check)
 - Continuous delivery of selected parameters
 - Every sample update (e.g. Strip-chart display)
 - Change only update (e.g. Strip-chart display)
 - Periodic / timed update (e.g. Display windows)
- Client determines telemetry parameter collection
 - Identifies parameters client application wishes to receive
Maintains one list for each registered client
 - Forwards client parameter buffers to specific application

Telemetry Subsystem



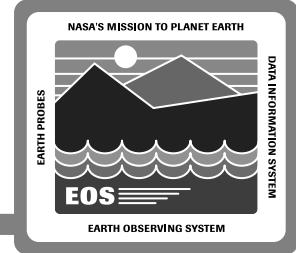
Dynamic Sizing of Parameter Table

- Grows automatically when recognizing new parameters
- Parameter newness based on unique ID key
 - Key can be of any type (e.g. integer, string)
 - Data-base defined, managed, and agreed upon by users
 - Typically integer Parameter Identifier (PID)
 - Fresh instance of Parameter Server required for each different key type

Loose coupling between Producers and Consumers

- Dynamic attachment and detachment of consumers
- Producers and Consumers resident on same or different hosts
 - Breaks away from shared memory
 - Moves toward distributed client / server applications

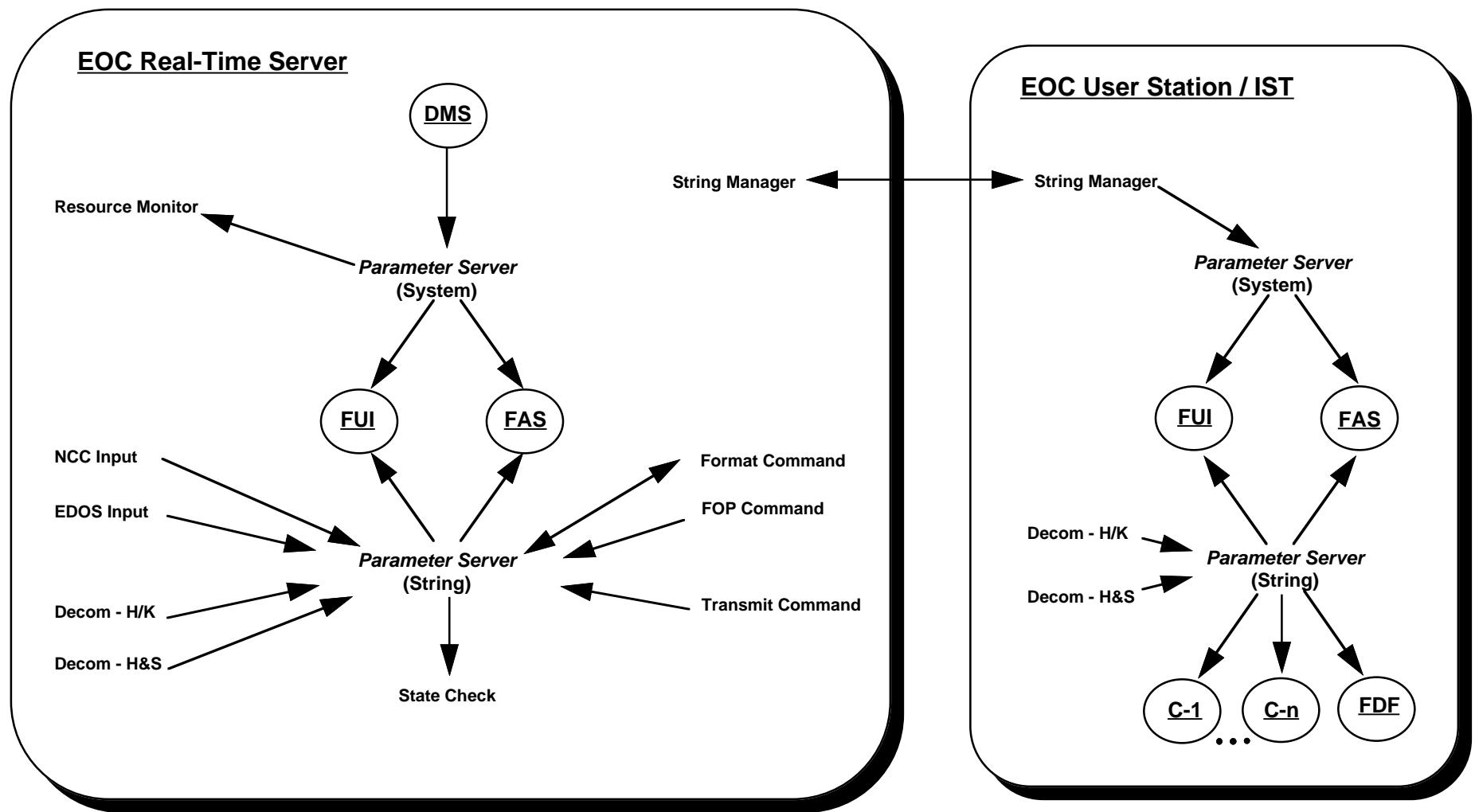
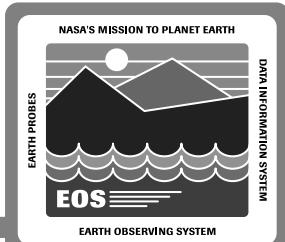
Telemetry Subsystem



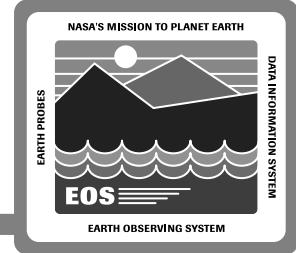
Parameter Server Roles

- **System Parameter Server**
 - Serves information vital to string management (e.g. h/w, s/w status)
Single instance configured for each host
 - Found on Real-Time Server and EOC User Station / IST
- **String Parameter Server**
 - Serves information specific to a logical string (e.g. Decom, Ground Telemetry, NCC and EDOS input)
Fresh instance configured for each logical string
 - Found on Real-Time Server and EOC User Station / IST
 - Gives internal and external users (such as FDF) a consistent software interface to FOS telemetry information

Telemetry Subsystem



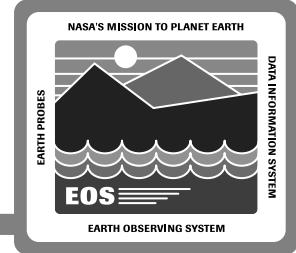
Telemetry Subsystem



Subsystem Processes

- Decom (prototyped)
 - Decommutes spacecraft and instrument telemetry
 - Calculates derived telemetry parameters
 - EU-converts and limit checks decommutated and derived parameters
- Diagnostic Memory Dump
 - Detects the start and completion of spacecraft or instrument computer memory dumps
 - Collects and stores the contents of downlinked memory dumps for subsequent CMS analysis (near real-time or off-line)

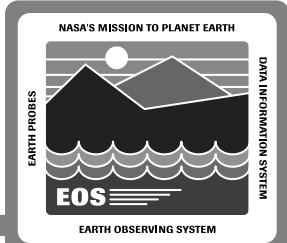
Telemetry Subsystem



Subsystem Processes

- **S/C State Check**
 - Assists in back-orbit command verification
 - Compares the spacecraft's state with an expected state
 - Expected state values available via CMS “on-the-fly” generation or telemetry baseline
- **Parameter Server**
 - Provides a parameter repository to / from which:
 - Parameter producing processes supply updated parameter values
 - Parameter consuming processes receive continuous or one shot parameter updates

Telemetry Subsystem



Real-Time Server

String Manager
Resource Monitor

NCC Input
NCC Output
EDOS Input
EDOS Output

Format Command
FOP Command
Transmit Command

**Decom
Memory Dump
State Check
Parameter Server**

COTS

Data Server

User Station

IST

String Manager

**Decom
Parameter Server**

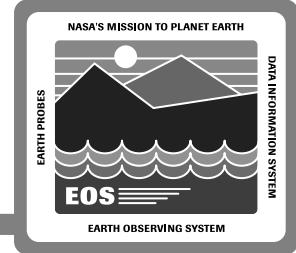
COTS

String Manager

**Decom
Parameter Server**

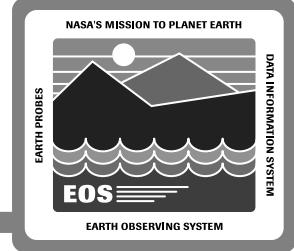
COTS

Command Subsystem



Concepts and Features

- Modular separation of responsibilities
 - Spacecraft bus command format (1553-B)
 - Ground to spacecraft protocol (COP-1)
 - Command package transmission (PLOP-1/2)
- Prime and Backup processing modes (hot backup)
 - Command processing synchronization for immediate fail-over
 - Gated command transmission prevents duplicate commands to spacecraft
- Real-time verification of stored command execution during contacts
- Historical trace of command activity and verification status

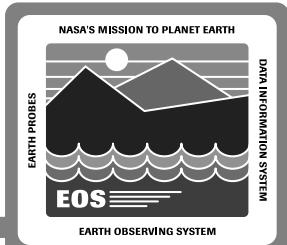


Command Subsystem

Subsystem Processes

- Format Command
 - Receives and validates command directives
 - Processes commands into spacecraft recognizable format
 - Manages command subsystem configuration changes
 - Verifies command execution
- FOP Command (prototyped)
 - Wraps commands received from Format Command process according to CCSDS standard (builds CLTUs)
- Transmit Command
 - Forwards CLTUs received from FOP Command process at specified uplink rate (PLOP-1/2)

Command Subsystem



Real-Time Server

String Manager
Resource Monitor

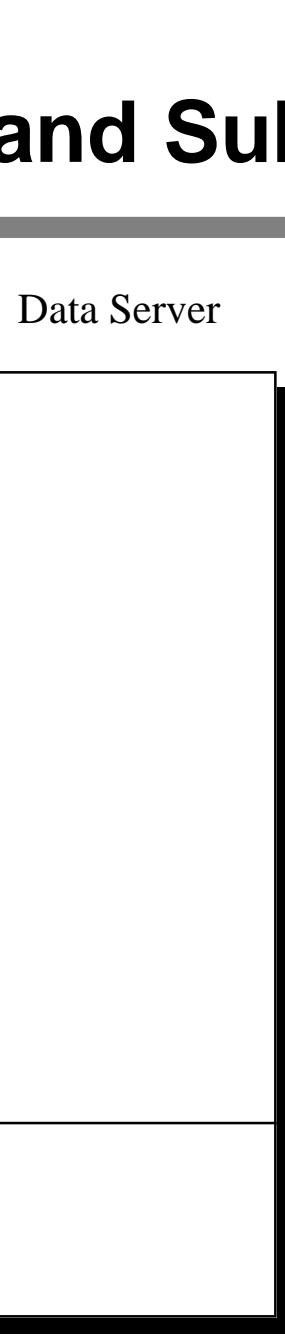
NCC Input
NCC Output
EDOS Input
EDOS Output

Format Command
FOP Command
Transmit Command

Decom
Memory Dump
State Check
Parameter Server

COTS

Data Server



User Station

String Manager

Decom
Parameter Server

COTS

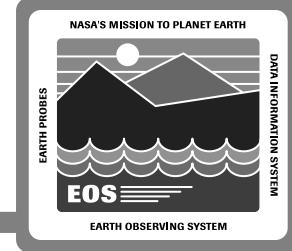
IST

String Manager

Decom
Parameter Server

COTS

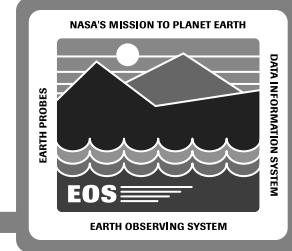
Real-time Contact Management Subsystem



Concepts and Features

- Concurrent processing of any / all ground message data types
 - NCC status, accounting, and performance messages
 - EDOS accounting messages
 - DSN monitor blocks
- Replay of raw, archived NCC, EDOS, DSN accounting messages and Monitor Blocks
 - Enhances off-line troubleshooting and analysis
- NCC, EDOS, DSN parameterized message fields
 - Permits real-time monitoring and statistics generation

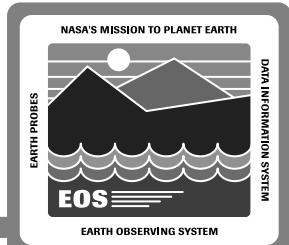
Real-time Contact Management Subsystem



Subsystem Processes

- NCC Input
 - Receives and processes NASCOM block format NCC performance messages
- NCC Output
 - Generates and transmits NASCOM block format NCC configuration messages
- EDOS Input
 - Receives and processes CODA format EDOS performance messages
- EDOS Output
 - Generates and transmits EDOS test messages

Real-time Contact Management Subsystem



Real-Time Server

String Manager
Resource Monitor

NCC Input
NCC Output
EDOS Input
EDOS Output

Format Command
FOP Command
Transmit Command

Decom
Memory Dump
State Check
Parameter Server

COTS

Data Server

User Station

IST

String Manager

Decom
Parameter Server

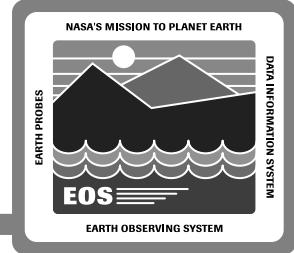
COTS

String Manager

Decom
Parameter Server

COTS

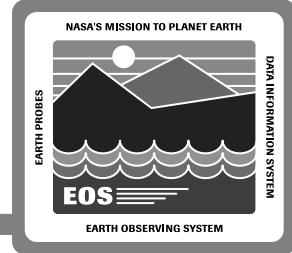
Real-time Hardware Utilization



Real-Time Server (RTS)

- Facilitate control and maintenance of critical and closely coupled resources via well-known locations
 - EOC hardware and software resource monitoring
 - NCC and EDOS communications / link management and statistic gathering
 - Command Processing
 - Comprehensive Telemetry Decommunication
- Provide platform conducive to contact automation
 - Critical and mandatory functions remain local
 - Ground-script control of routine contact activities

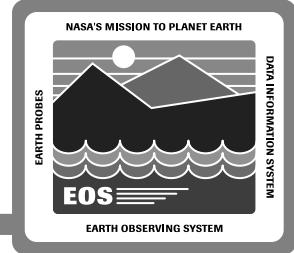
Real-time Hardware Utilization



Real-Time Server (cont.)

- Facilitate fail-over and security of critical real-time processes
 - Ensure known and controllable location of Prime and Backup processes
 - Provide protected environment that avoids accidental hardware or software configuration changes
- Divert POSIX real-time extensions requirement away from local User Stations
 - Focus and limit need to EOC specific functionalities (CMD, RCM)

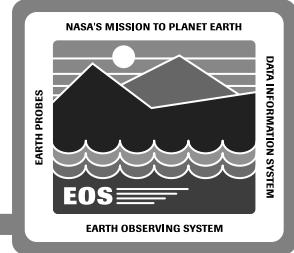
Real-time Hardware Utilization



User Station (US)

- Promote configuration flexibility
 - Mobile positioning of FOT and IOT personnel
 - Freedom of joining selected / multiple logical strings
 - Push local telemetry processing options out to user
 - Consistency of mirrored configuration
 - Freedom of tailored configuration
- Provide system scalability and extensibility
 - Minimize restrictions on number and types of users (personnel and applications)
 - EOC positions and applications added without increasing RTS and network load (e.g. during launch and orbit raising)
 - Mechanism used on heritage control centers (e.g. Space Telescope)

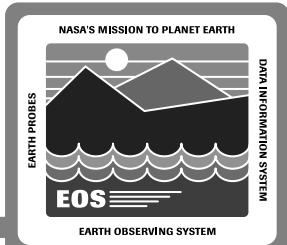
Real-time Hardware Utilization



Real-time Downward Scalability Options

- Real-time POCC-in-a-box
 - Platform for low-end control center applications
 - Software architected to accommodate total workstation solution
 - Combine RTS and US functions and processes onto workstation
 - Uses : Mini Control Center (simple, short-term missions)
 Mobile Control Center
 Instrument or Spacecraft bus test platform
- PC-based User Station (prototype in progress)
 - Platform for low-end user station applications
 - Unix operating system (e.g. Solaris)
 - Avenue toward alternate Posix O.S. (e.g. NT)
 - Long-term portability, migration paths

Real-time Task Distribution



Real-Time Server

String Manager
Resource Monitor

NCC Input
NCC Output
EDOS Input
EDOS Output

Format Command
FOP Command
Transmit Command

Decom
Memory Dump
State Check
Parameter Server

COTS

Data Server

User Station

IST

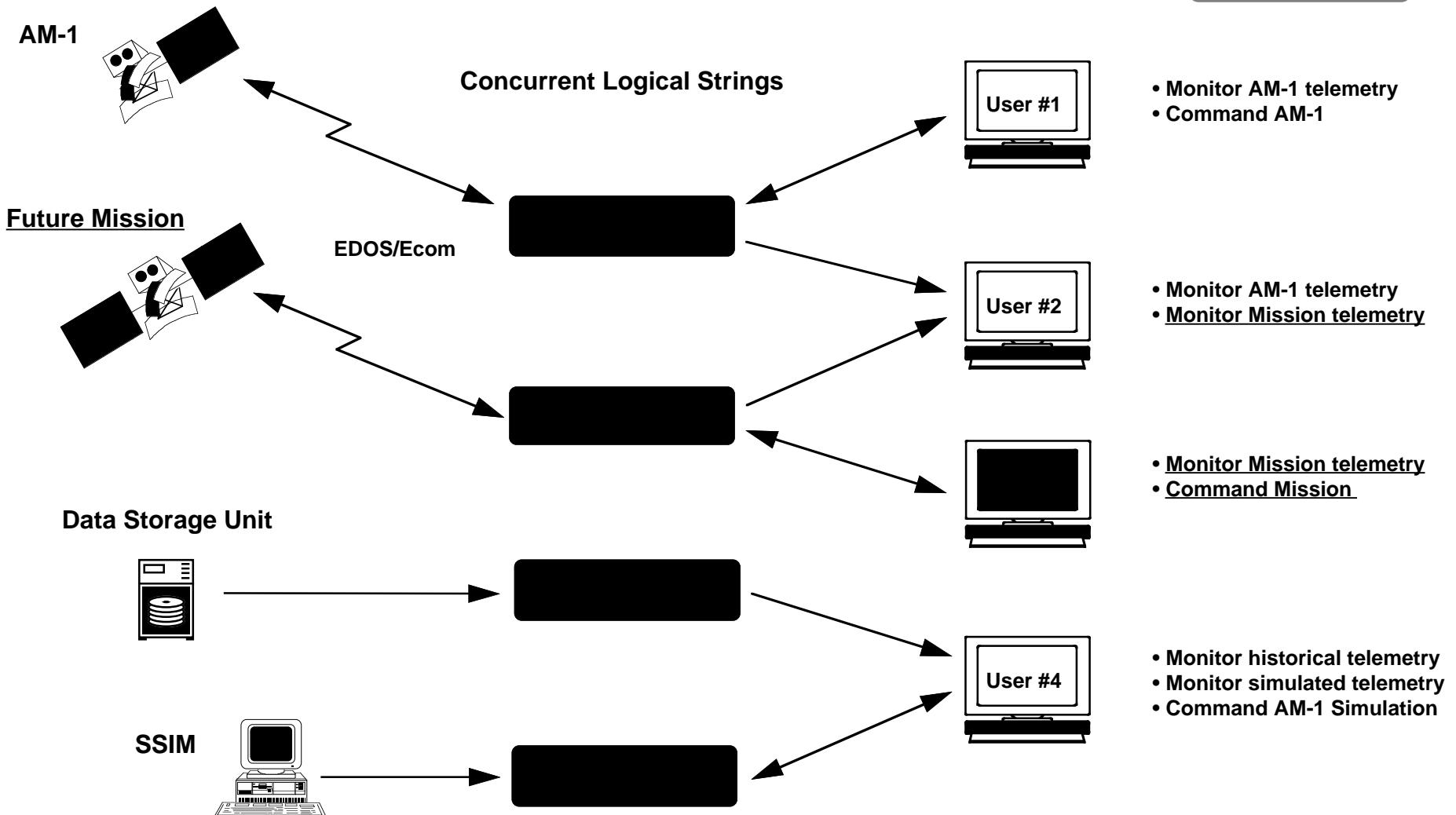
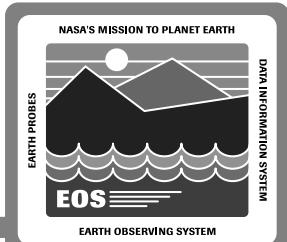
String Manager
Decom
Parameter Server

COTS

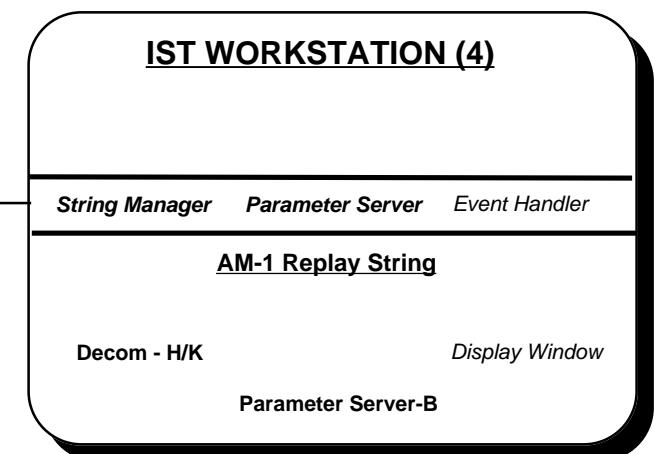
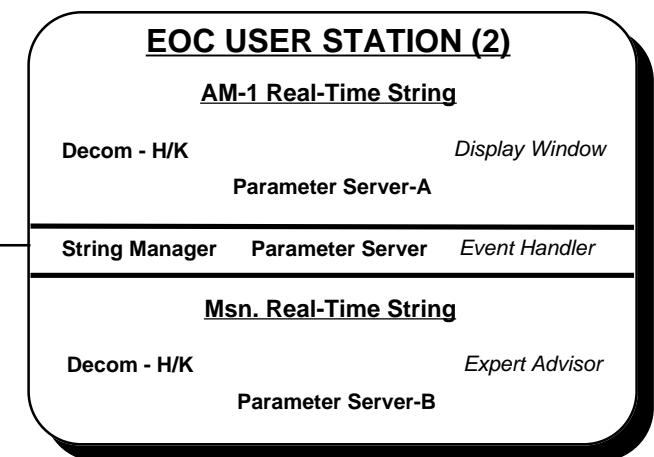
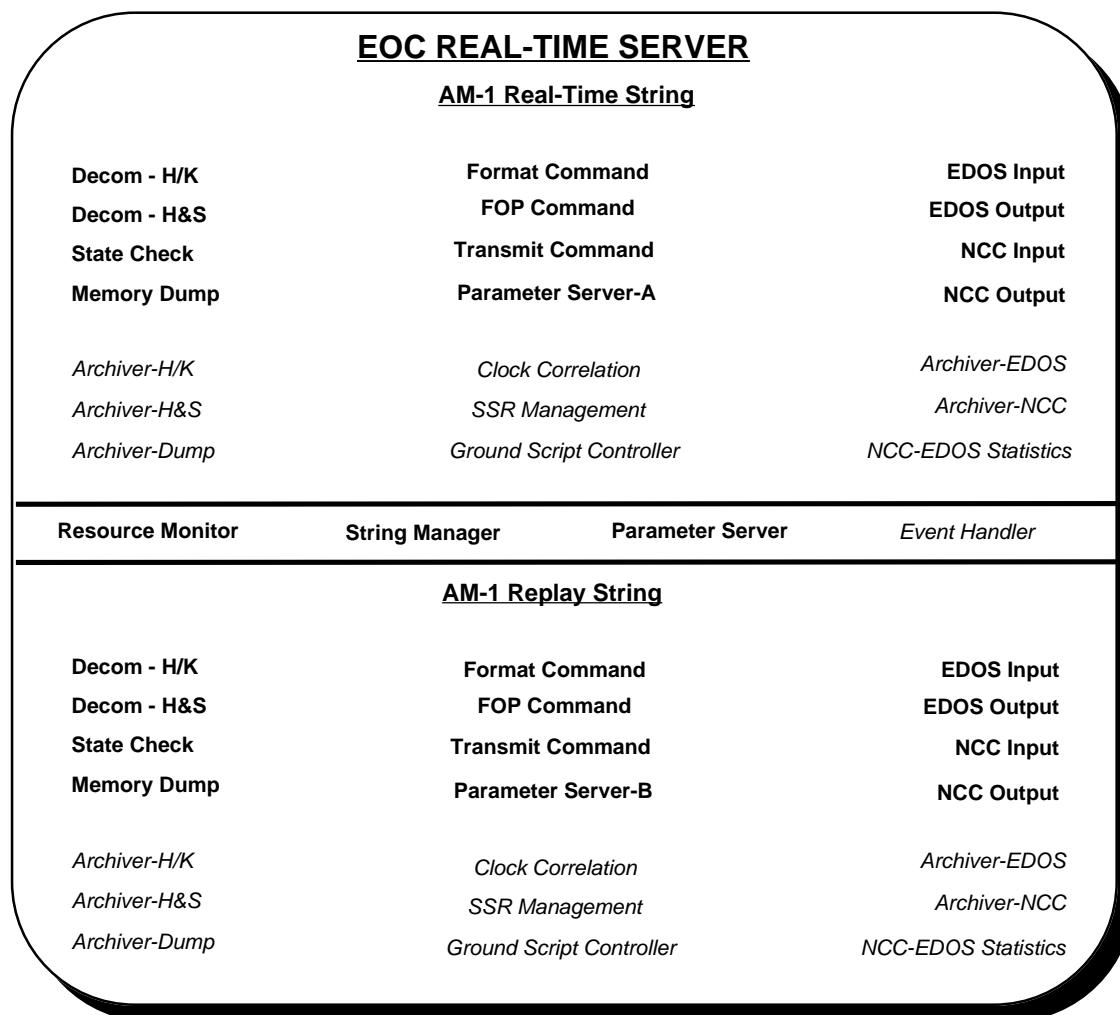
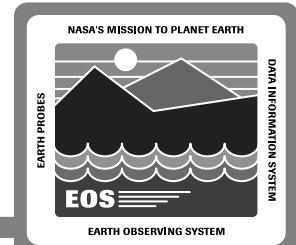
String Manager
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Parameter Server

COTS

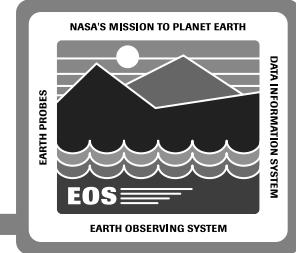
Real-time Task Distribution



Real-time Task Distribution



Real-time Introductions



Presenters:

Carrie Williams

- Resource Management Subsystem
- Real-time Contact Management Subsystem

Jules Junker

- Telemetry Subsystem

J.B. Wilson

- Command Subsystem